



# **Powering Mexico's Future**

## **An In-Depth Look at Long-Term Electricity Market Developments**

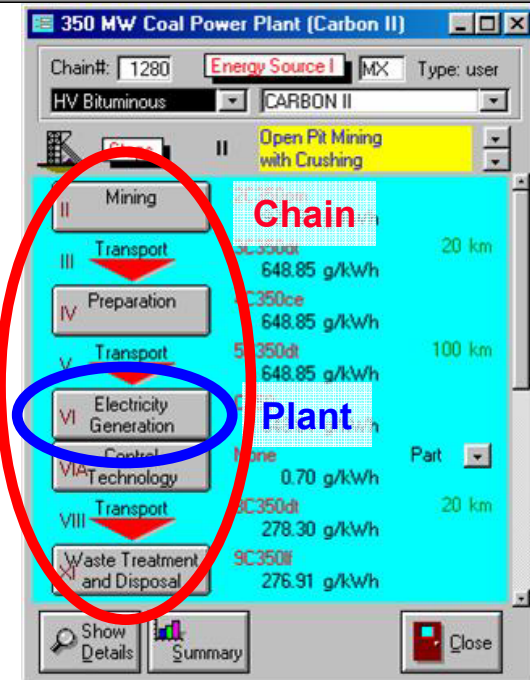
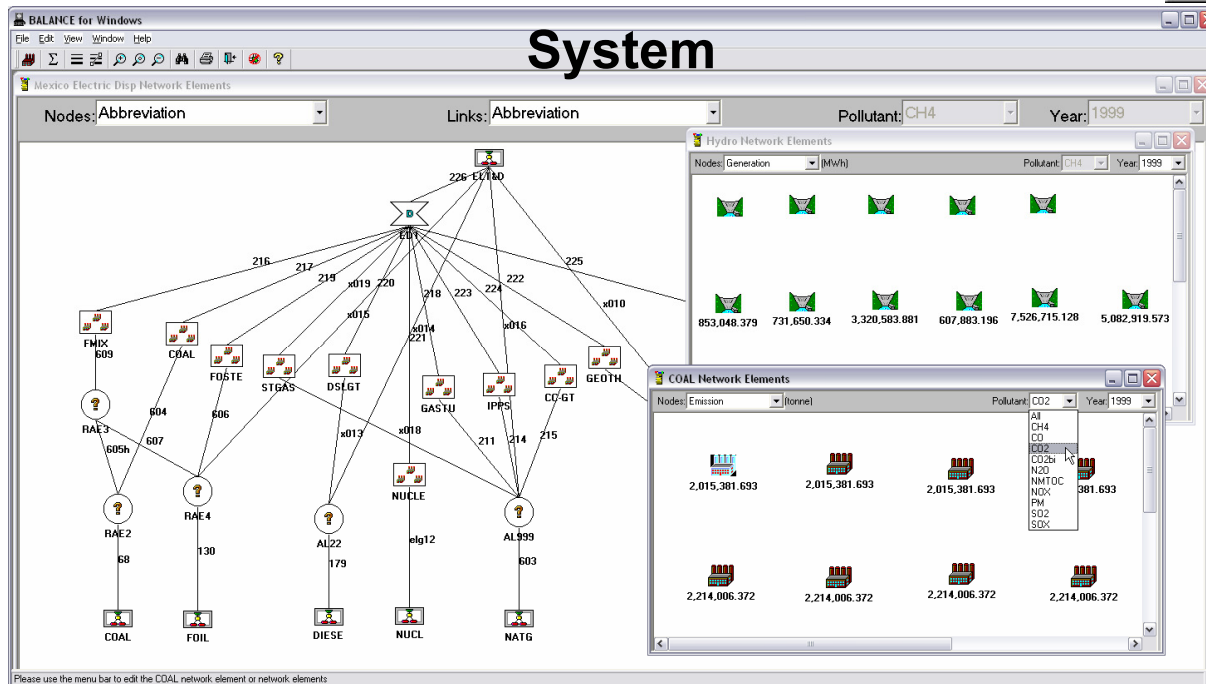
**Study Conducted by a Team of Analysts from:**

***Comisión Federal de Electricidad (CFE)***  
***Secretaría de Energía (SENER)***  
***Universidad Nacional Autónoma de México (UNAM)***  
***Instituto de Investigaciones Eléctricas (IIE)***  
***Argonne National Laboratory (ANL)***

**Presented on October 21, 2003 at the 23<sup>rd</sup> IAEE North American Conference in Mexico City**

# The Team of Analysts Used the DECADES-WASP Tool Set to Conduct the Analysis

- Plant-level analysis for project evaluation
- Fuel chain-level analysis for comparative assessment of entire fuel chains
- System-level analysis for full-scale system expansion analysis up to 30 years using a dynamic optimization approach



# The Team Analyzed a Total of 14 Scenarios

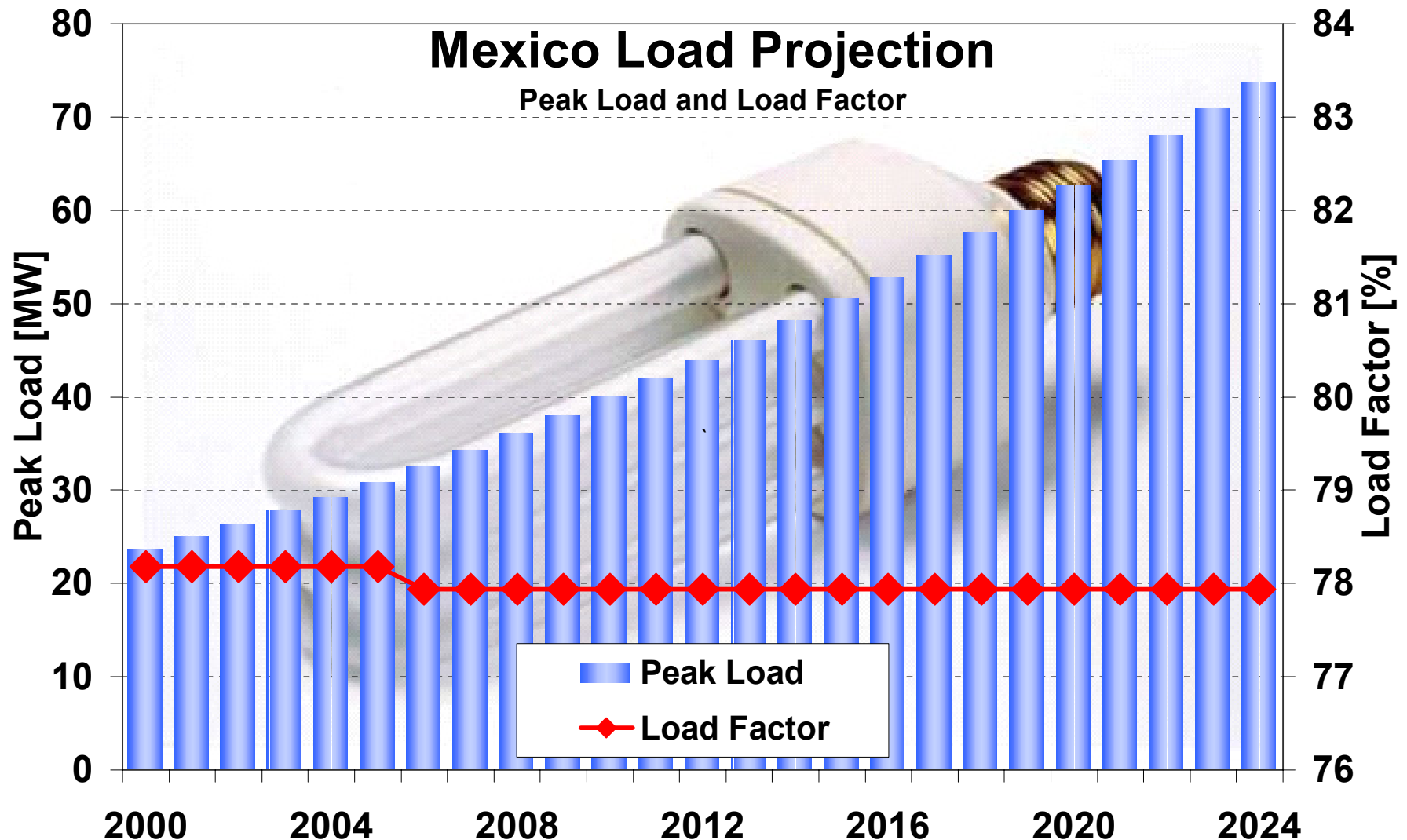
- **Reference case**
- **High-load growth case (6.5% instead of 5.6% per year)**
- **Limitations on natural gas supply**
  - **Limit on annual additions of combined cycle units**
  - Limit on power sector gas supply (supply constant after 2010)
- **Variations on fossil fuel prices**
  - Natural gas increases to 4.0 instead of 2.9 \$/mmbtu
  - **Natural gas peaks at \$12.0/mmbtu and then declines to \$4.0/mmbtu by 2024**
- **Nuclear scenario**
  - One forced nuclear unit
  - **Reduction in nuclear capital costs to the point where nuclear enters the market**
- **Variations on discount rate (8% to 12%; 10% under Base Case)**
- **Variations on target system reliability**
  - Increased reliability (loss of load probability of 1 day per year instead of 3 days)
  - Decreased reliability (LOLP of 5 days)
  - Decrease in system reserve margin

# Reference Case General Assumptions

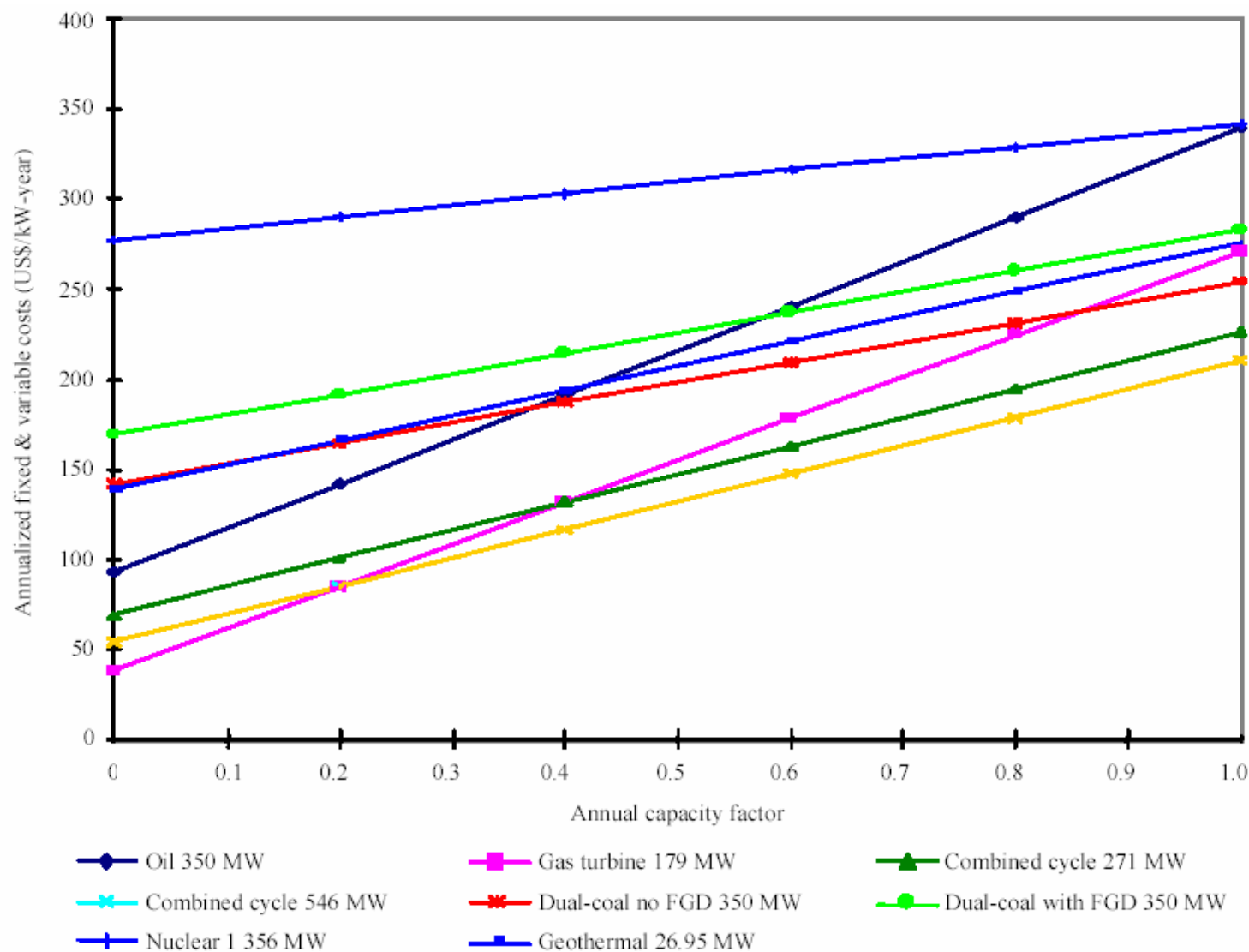
- Discount rate of 10%
- Cost of energy-not-served of 1.5 \$/kWh
- Target loss-of-load probability of 3 days/year or 0.82%
- Target range for system reserve margin of 10-30%
- Three seasons for inter-annual load variations (March-June, July-October, November-February)
- Three hydrological conditions and associated probabilities of occurrence
  - Dry: 19.0%
  - Medium: 58.7%
  - Wet: 22.3%
- Fuel prices according to the following table

Year	Fuel oil barrels	Natural gas 1000 cf	Imported coal 1000 kg (0.7% sulfur)	Enriched uranium g
1998	17.69	2.88	31.15	2.02
2027	20.70	2.95	25.99	2.34

# Reference Case Assumption: Peak Load Grows from 23.5 GW (2000) to 73.7 GW (2024)



# The List of Expansion Candidate Technologies Was Narrowed Down from a Larger Set by Using Screening Curves



# Final List of Candidate Technologies For System Expansion Includes the Following

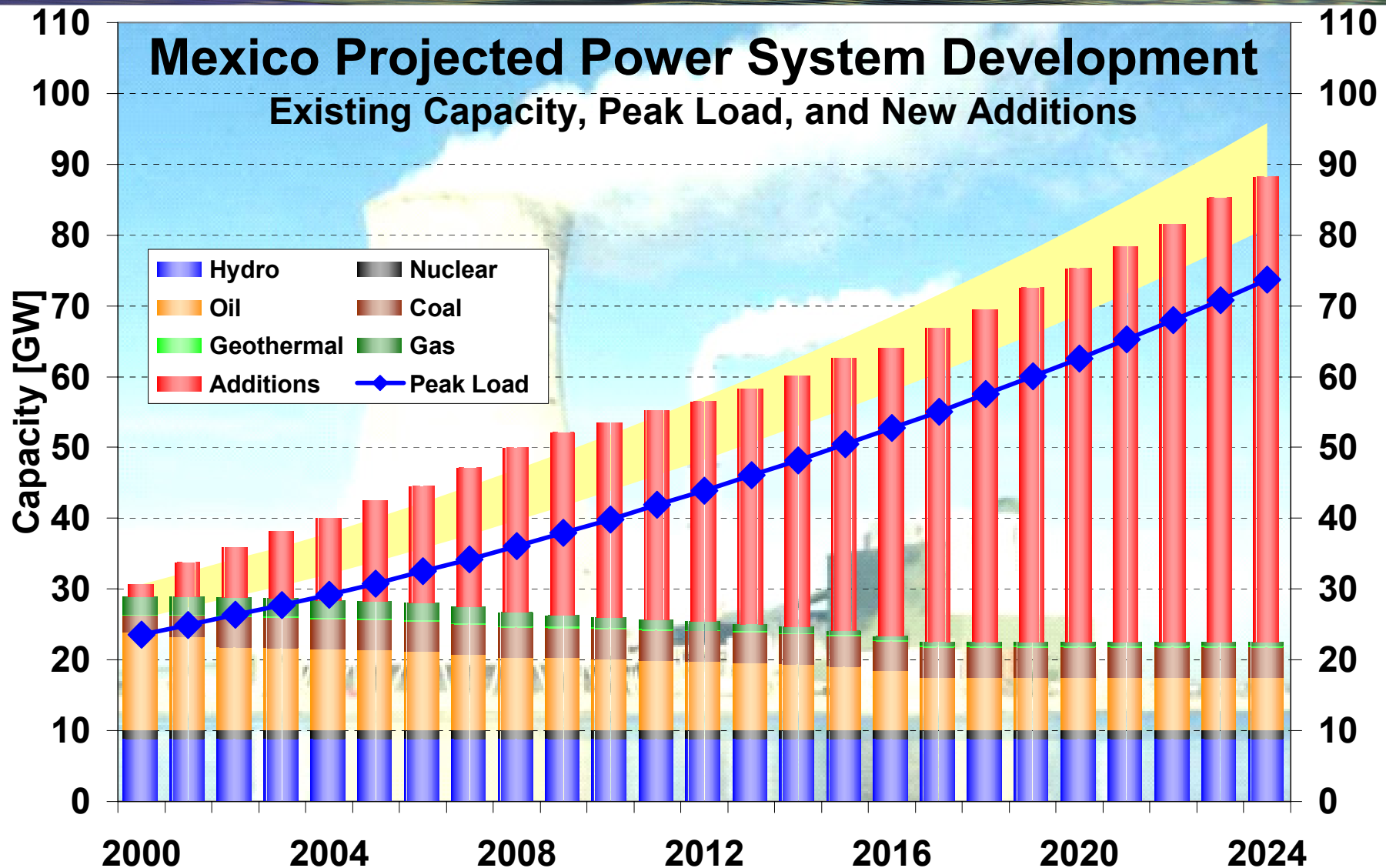
- Information comes from COPAR/CFE compiled from information on recently constructed plants, plants under construction, information from other countries, and information from plant manufacturers; costs are in US\$1998

Candidate	Capacity [MW]	Heat Rate [kcal/kWh]	Capital Cost incl. IDC [\$/kW]	Plant Life [years]	Construction Period [years]	IDC [%]
Gas Turbine	175	2,624	346	30	2	8.1
CCGT	527	1,763	427	30	2	8.1
Coal	310	2,597	1,468	30	4	15.6
Nuclear	1,314	2,570	2,485	40	8	29.2



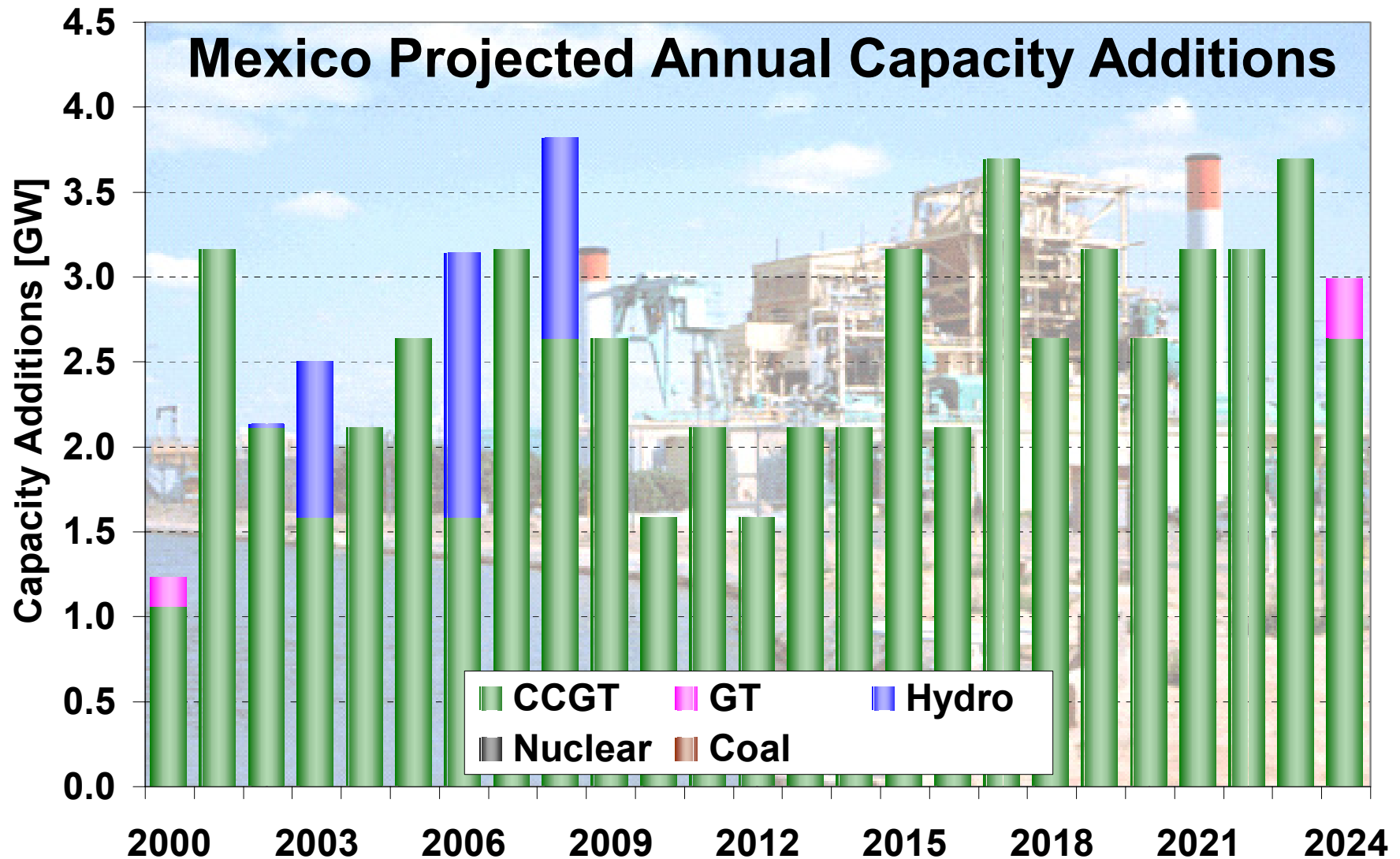
# Capacity Additions 2000-2010: 26.9 GW

## Capacity Additions 2000-2024: 65.2 GW

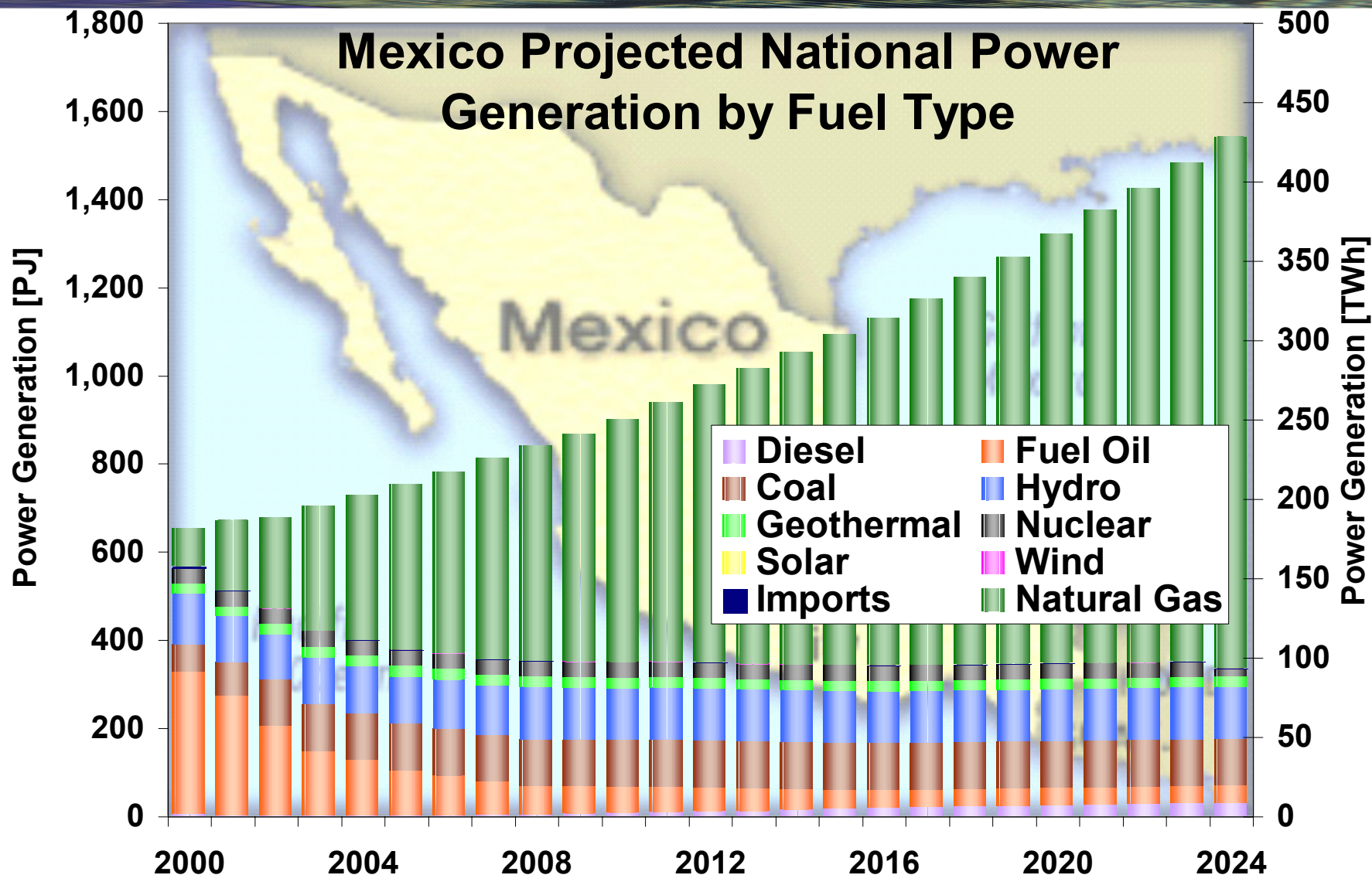




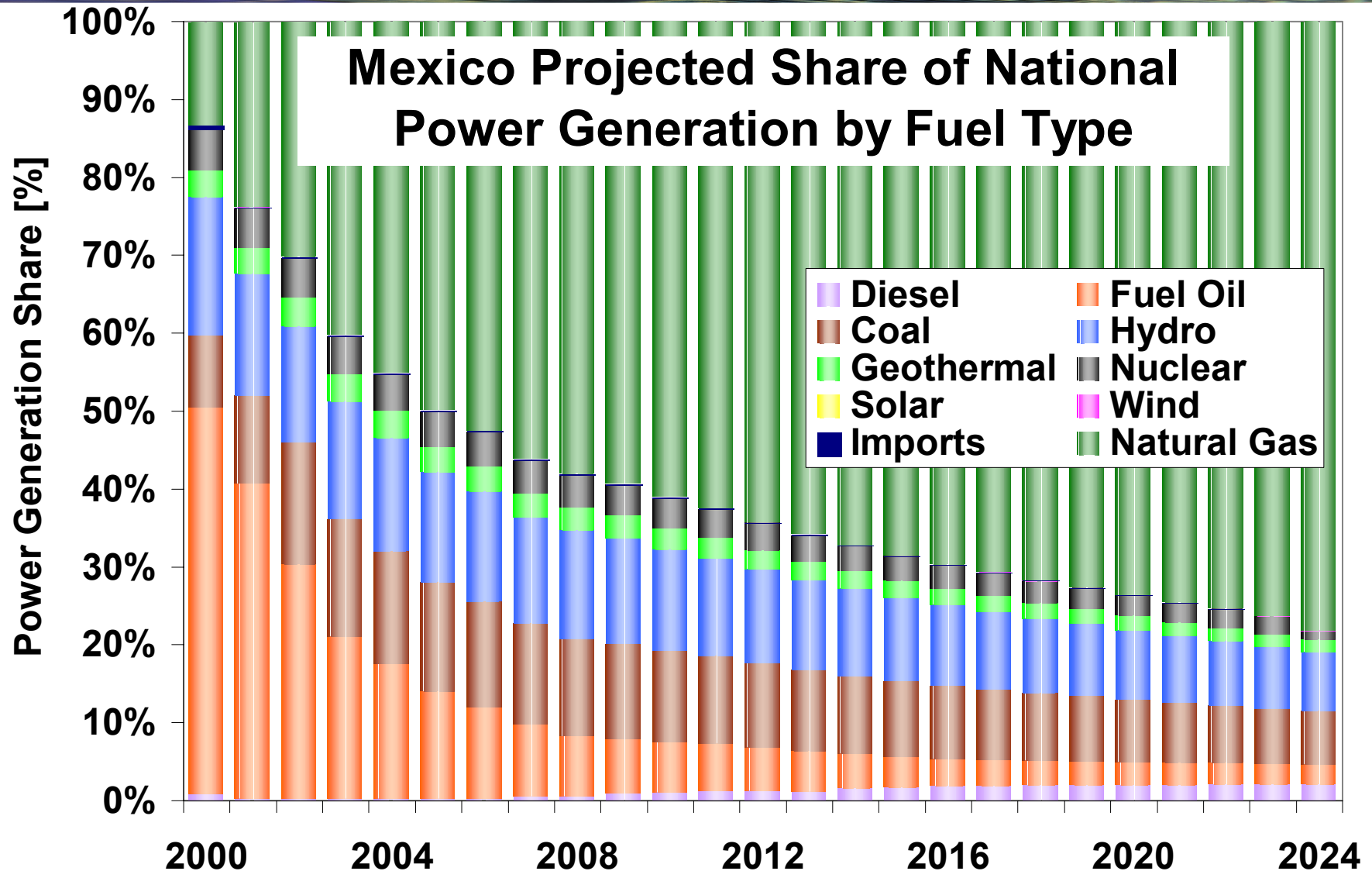
# Reference Case Capacity Additions Are Dominated by Natural Gas



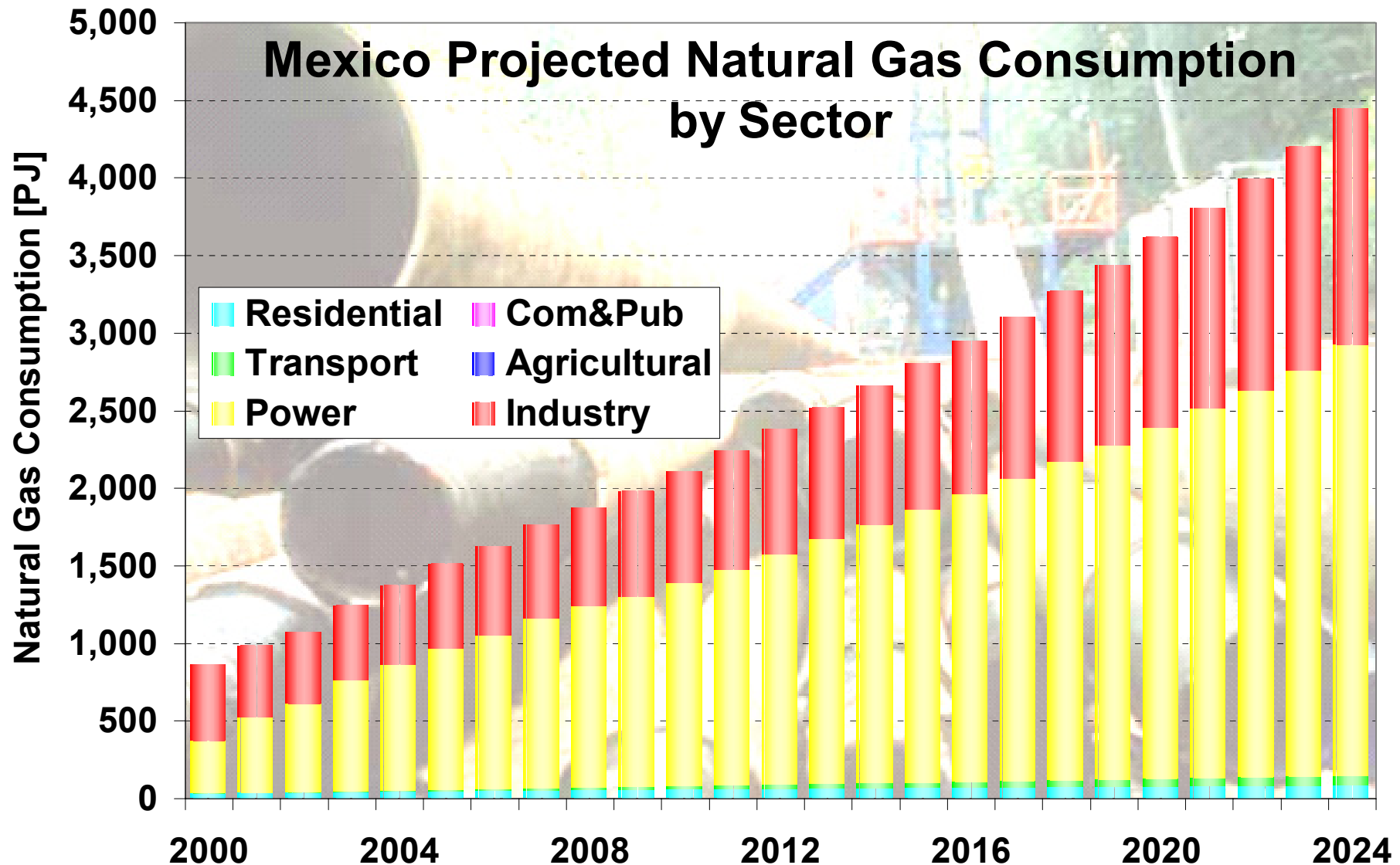
# Gas-Fired Power Generation Grows at 11.6% per Year from 24 TWh (2000) to 335 TWh (2024)



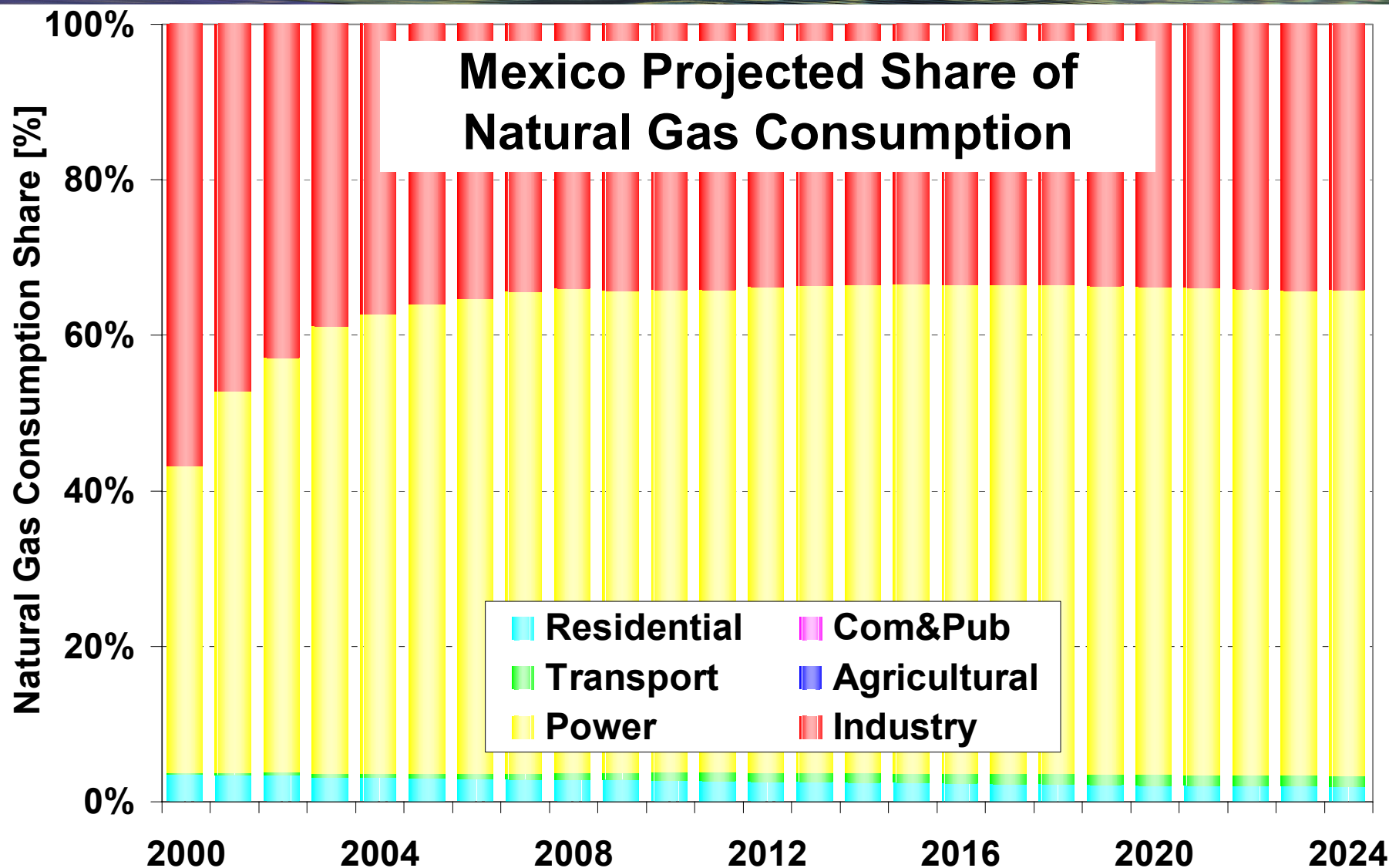
# Natural Gas-Fired Generation Will Account for 78% of Total Generation by 2024, up from 13% in 2000



**Power Sector Gas is Projected to Grow at 9.2%/yr from 339 PJ (2000) to 2,780 PJ (2024); Overall Gas Demand Grows at 7.1%/yr from 858 PJ (2000) to 4,447 PJ (2024)**

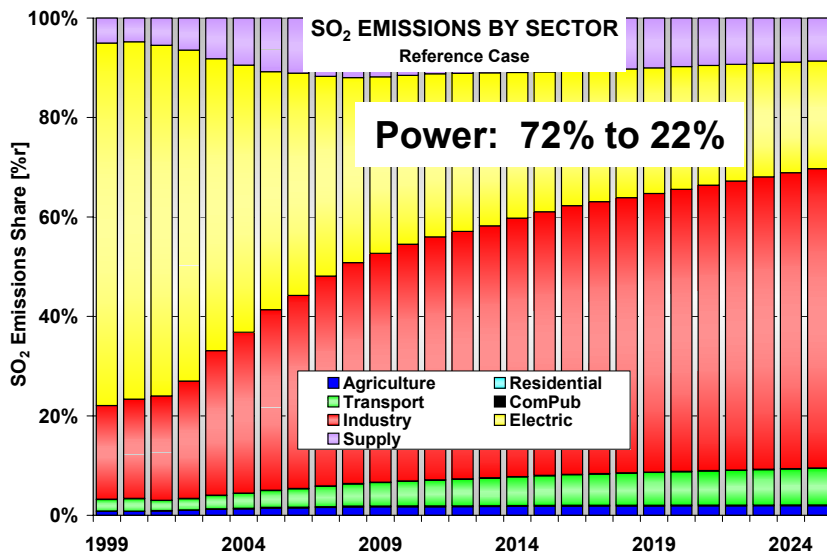
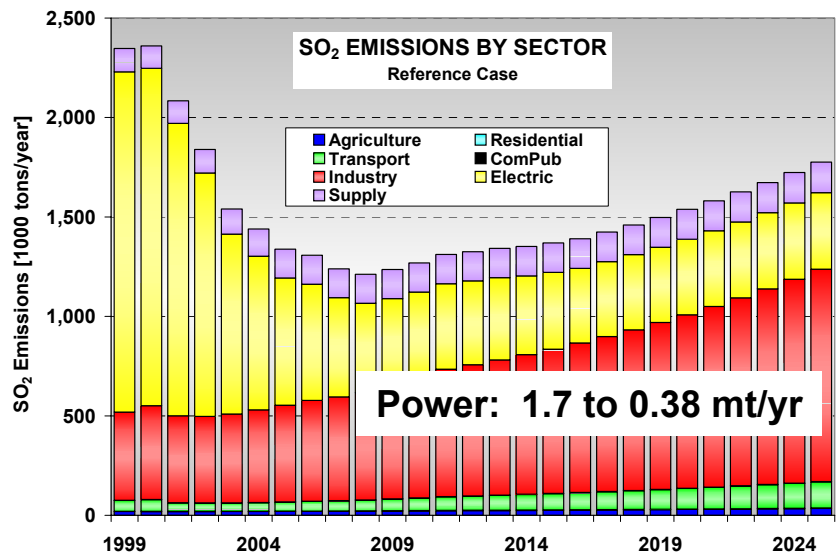
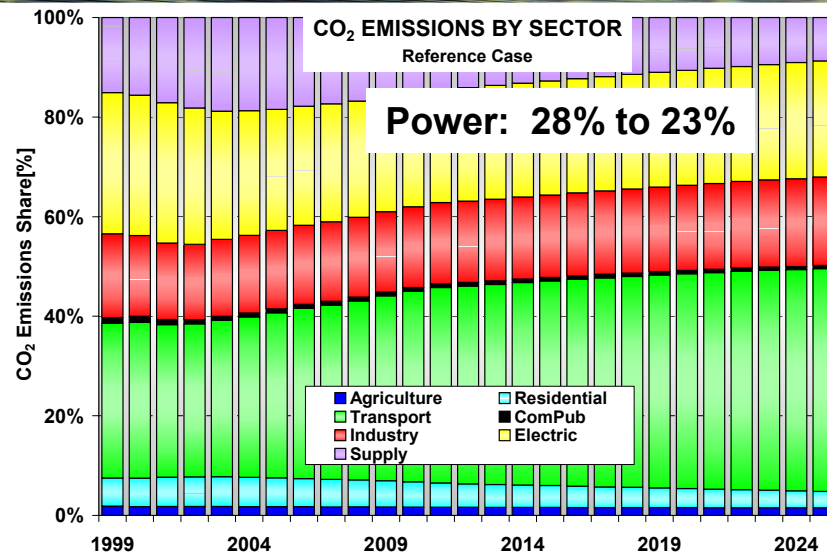
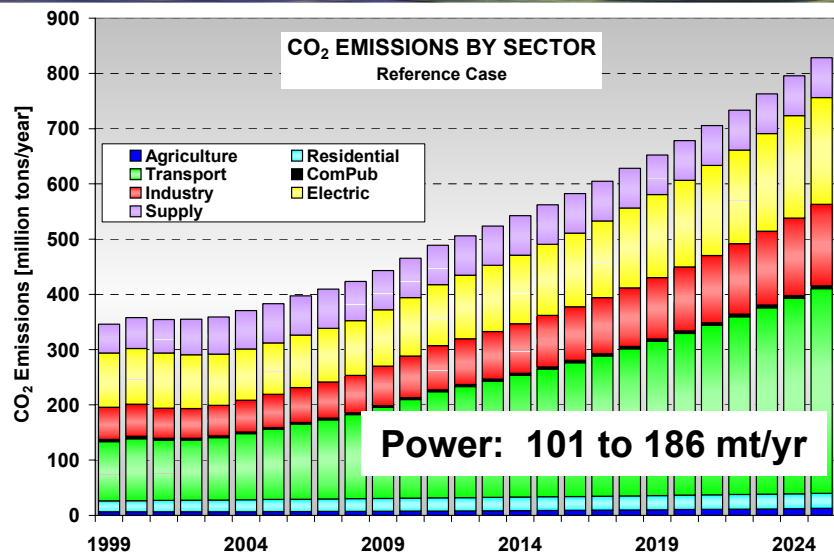


# Power Sector Will Account for 63% of Total Gas Demand by 2024, up from 39% in 2000



# Reference Case Emissions by Sector:

**CO<sub>2</sub> will Increase from 346 to 828 million tons/year**  
**SO<sub>2</sub> will Decrease from 2.3 to 1.8 million tons/year**



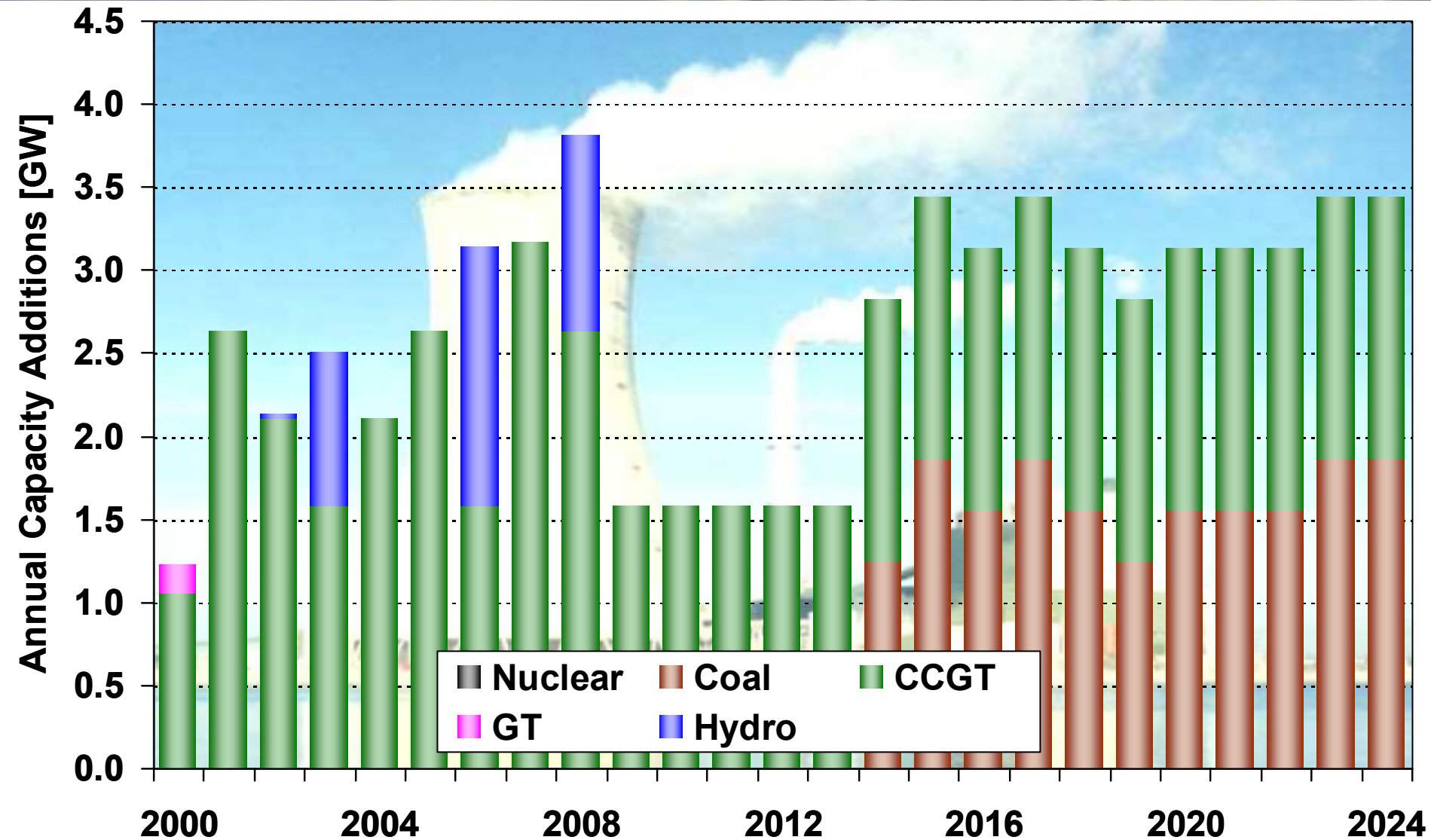
A map of Mexico is shown in the background, colored in a light yellow or tan hue. The map is centered on the continent of North America, with the surrounding oceans in a light blue color. The text is overlaid on the map.

## **Results for Limited Gas Supply Scenario**

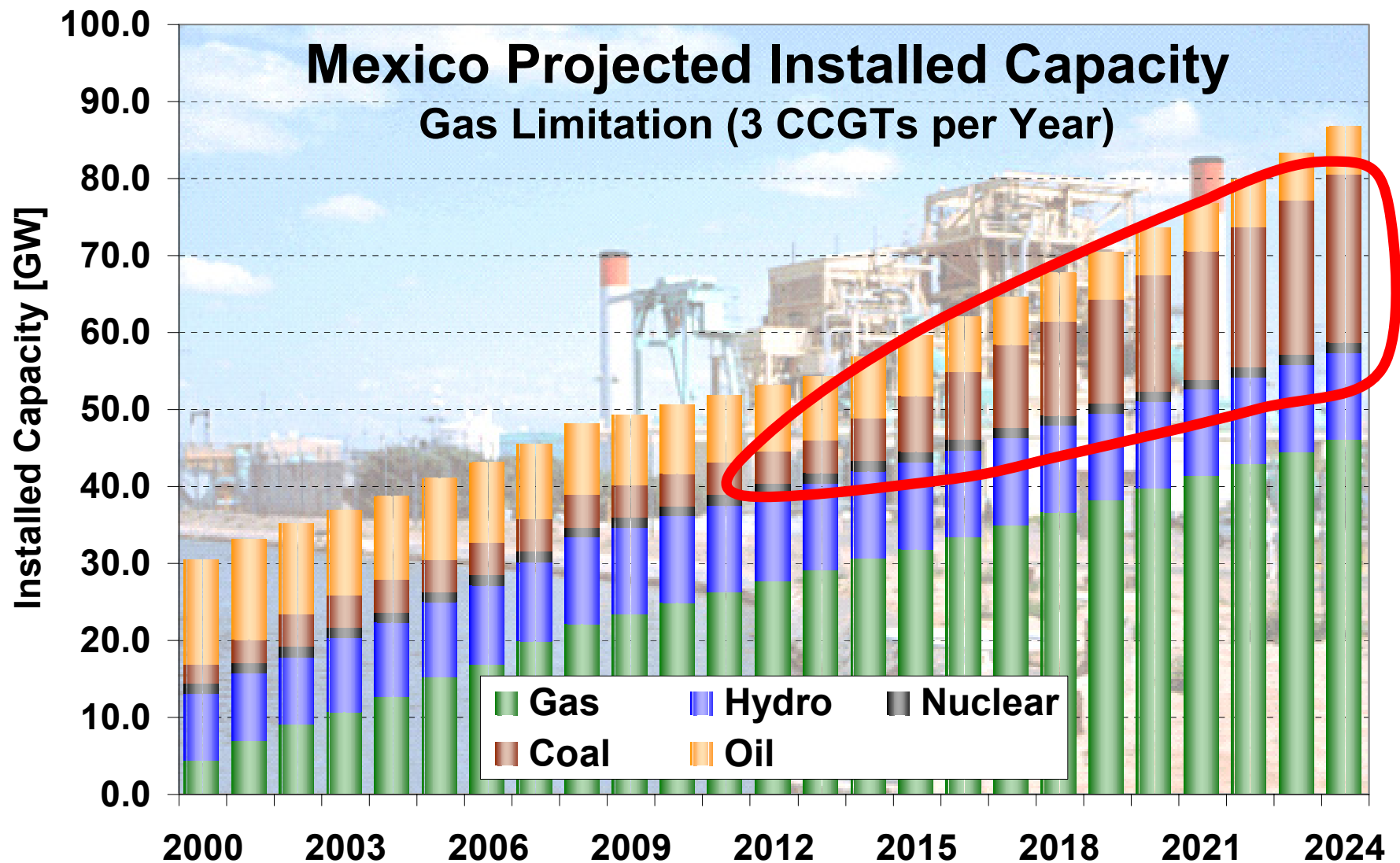
**Maximum of 3 CCGT Units per Year**



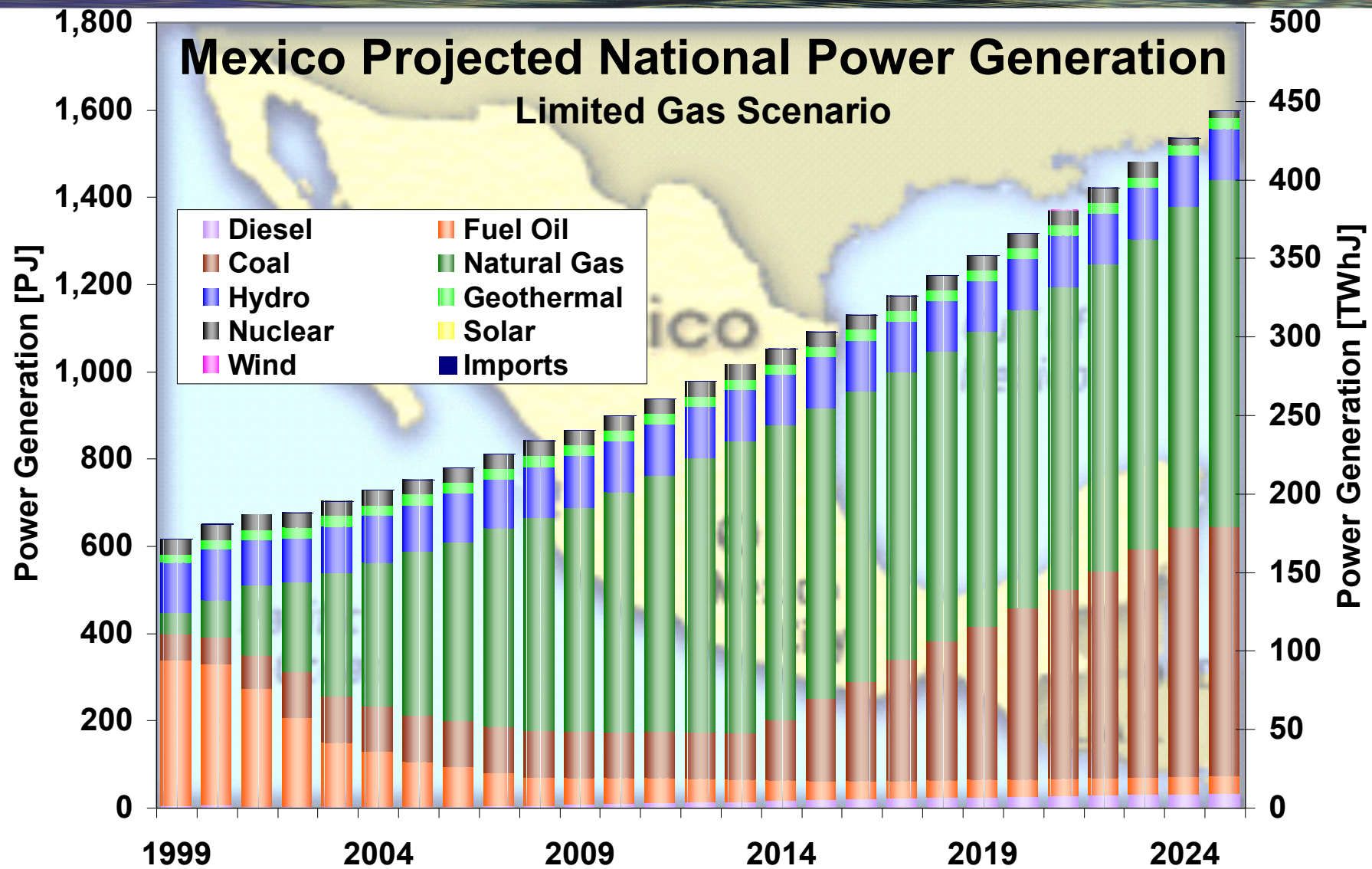
# With CCGT Limitation, A Total of 57 Coal Units Enter the Market and Replace Mostly 33 CCGT Units Starting in 2014



# By 2024, CCGT Limitation Results in 17.7 GW of Coal Capacity Replacing 17.7 GW of CCGT Capacity



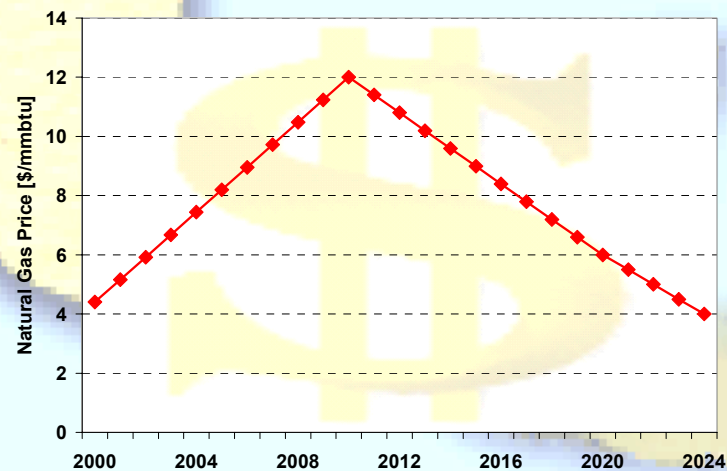
# By 2024, Coal Replaces about 37% of Gas Generation but Still Accounts for 48% of Total Generation; Reduces Power Sector Gas Demand by 35% and Overall Gas Demand by 22% (2024)



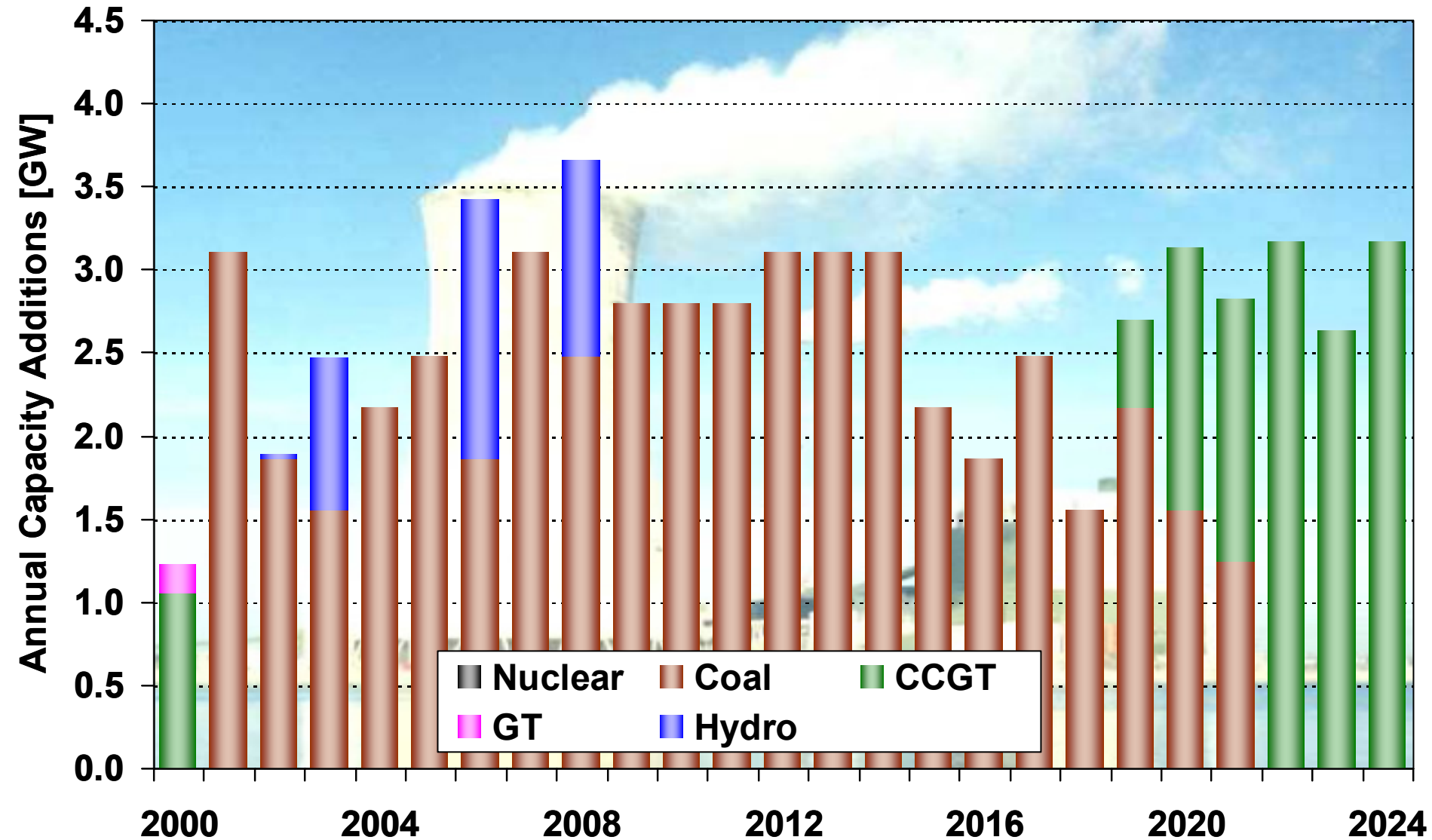
## Results for Natural Gas Price Scenario

**Gas Price Peaks at  
\$12.0/mmbtu (2010)**

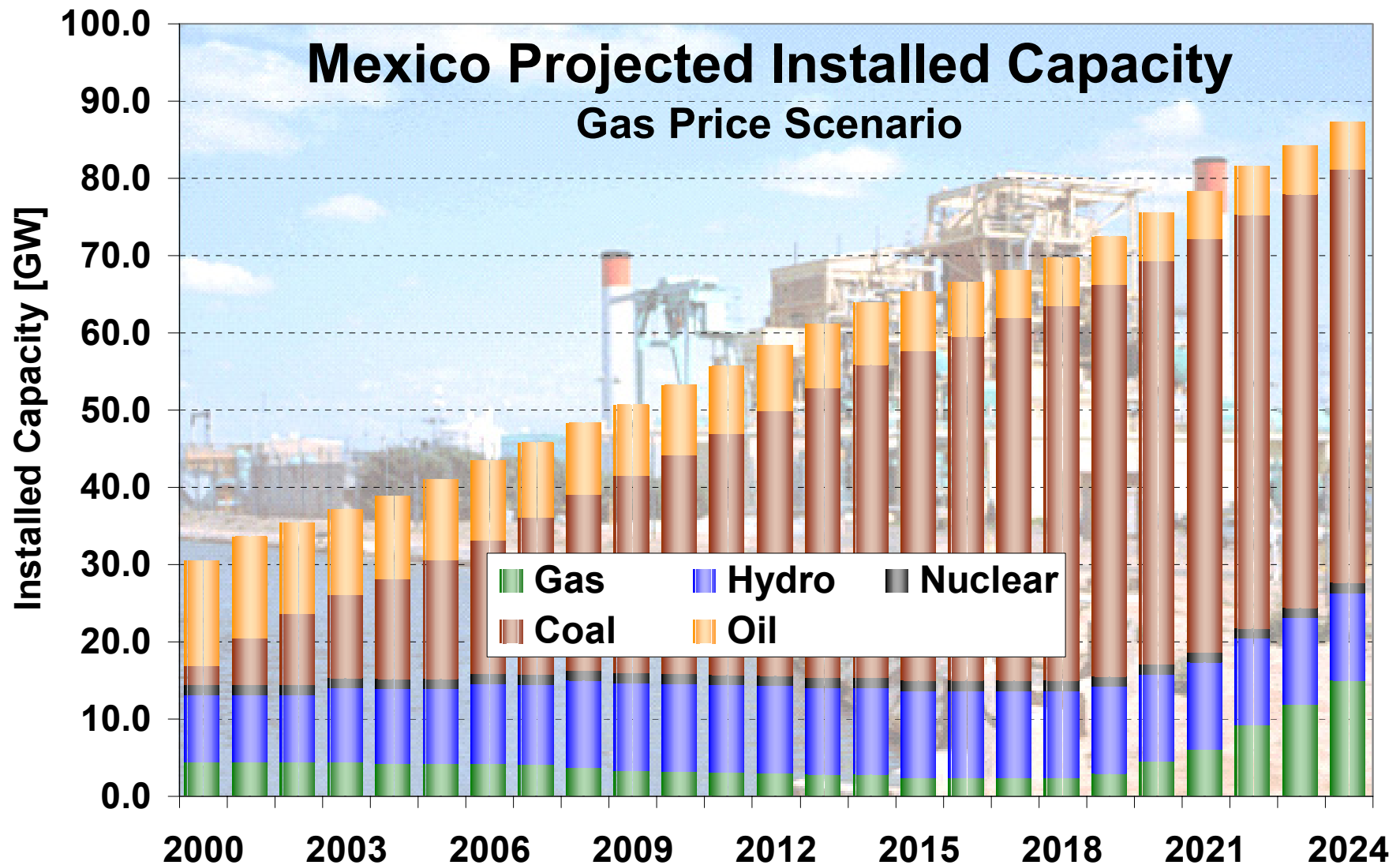
**Then Declines to  
\$4.0/mmbtu (2024)**



# At a High-Gas Price, A Total of 159 Coal Units Enter the Market and Replace Mostly 92 CCGT Units Starting in 2001



# Under High-Gas-Price Scenario, Coal Dominates the Expansion with a Total of 53 GW of Coal Capacity Added by 2024



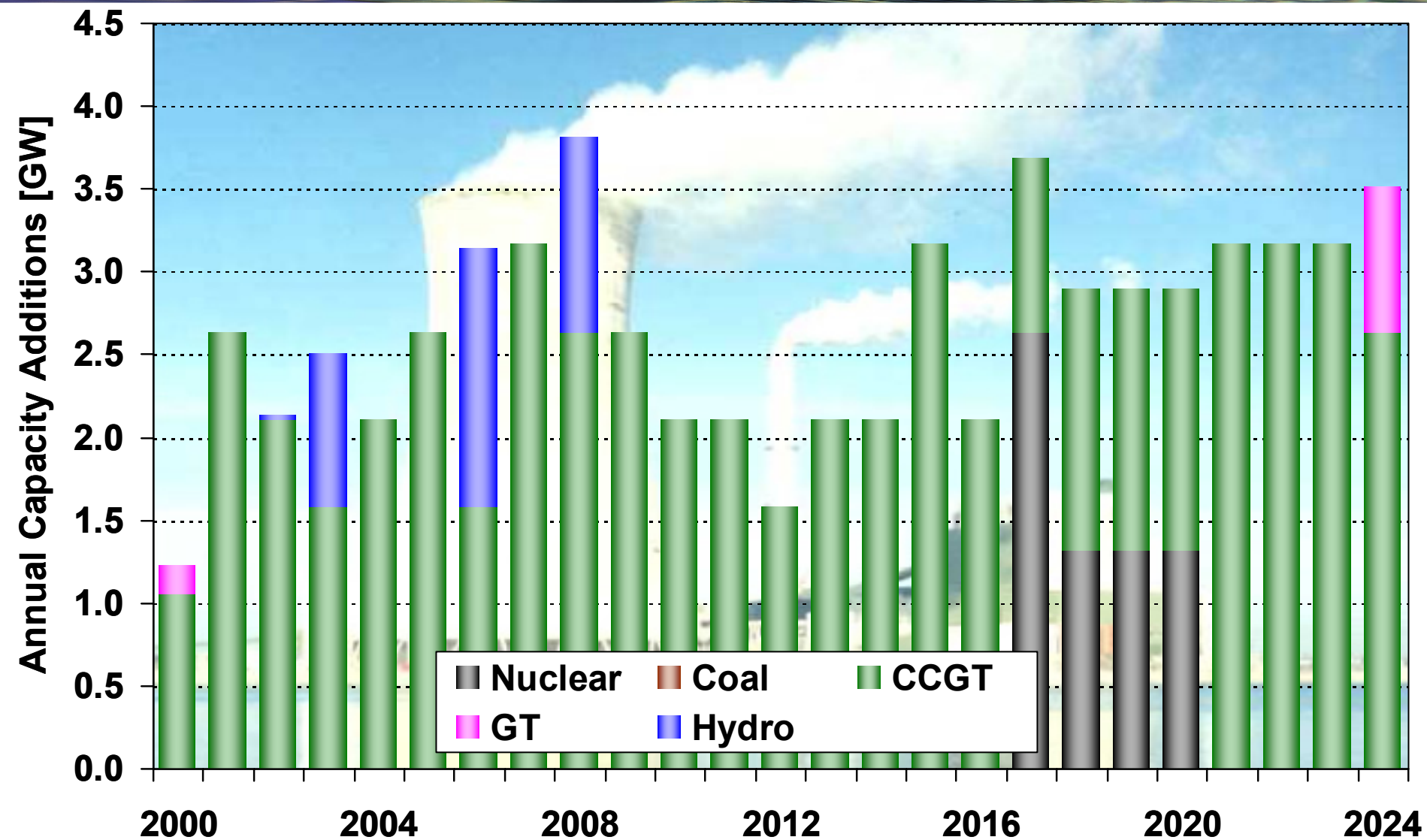
A map of Mexico is shown in the background, colored in a light yellow or tan hue. The map is centered on the continent of North America, with the surrounding oceans in a light blue color. The text is overlaid on the map.

## **Results for Nuclear Scenario**

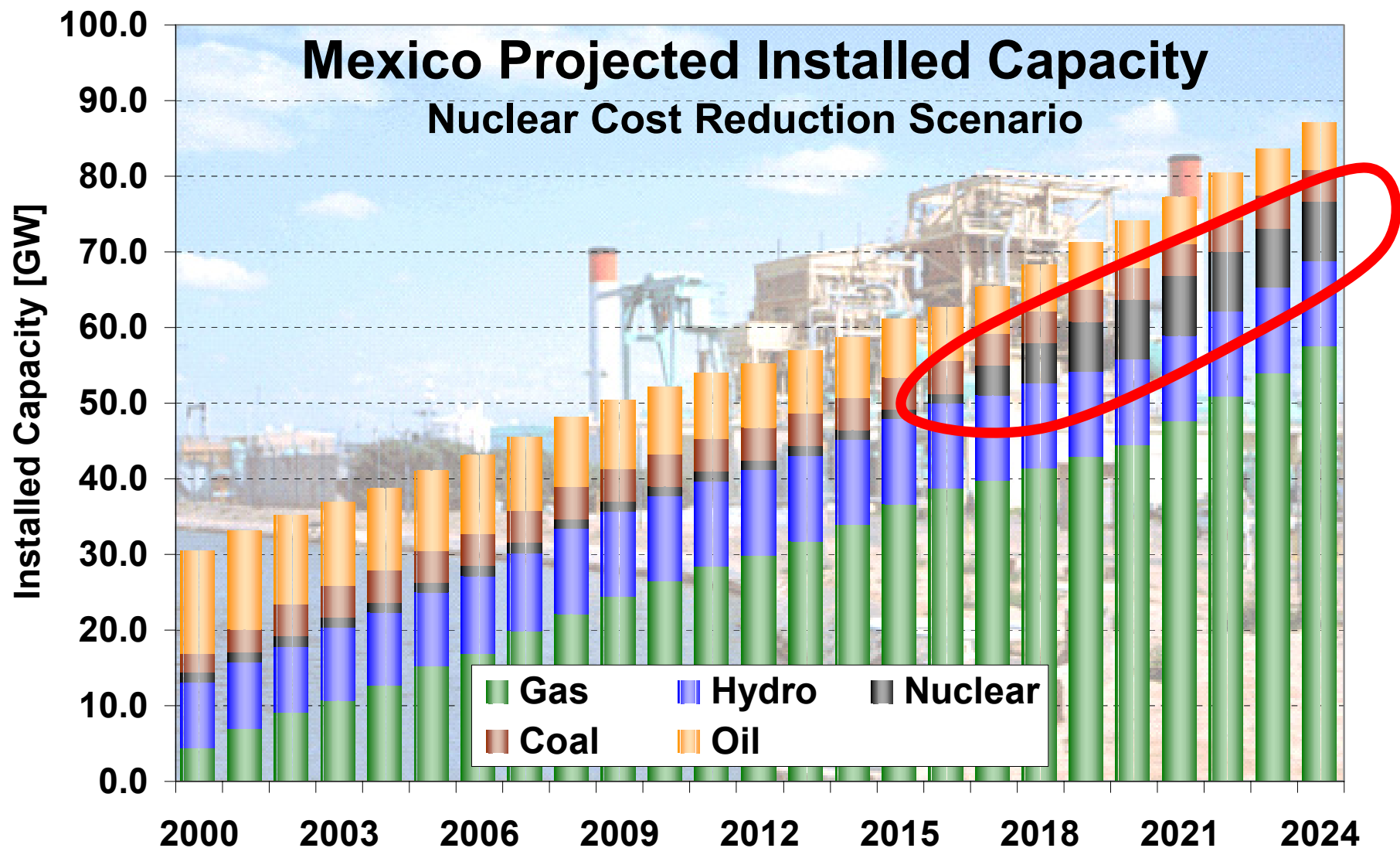
**Cost Reduction To Test Market Entry Barrier**



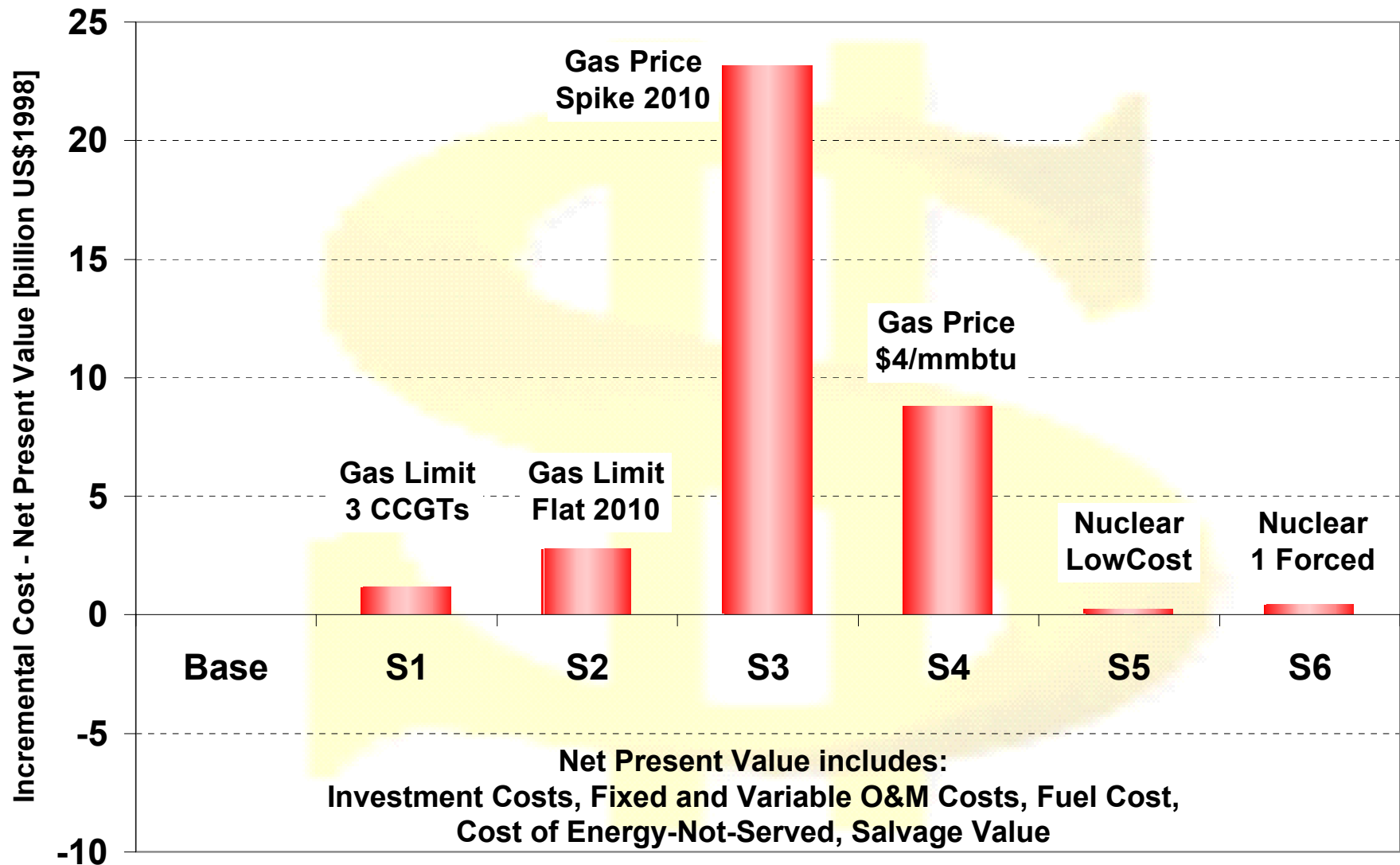
# A Total of 5 Nuclear Units Enter the Market and Replace Mostly CCGT Units Starting in 2017 if Costs are Reduced from \$2,485/kW to \$1,292/kW (48% Reduction)



# By 2024, 6.5 GW of Nuclear Capacity Replaces About 6.8 GW of CCGT Capacity



# Summary Economic Comparison of Various Scenarios



# Concluding Remarks

- **Reference Case**

- Natural gas will be the primary fuel of choice for power generation accounting for up to 63% of total gas demand
- The strong growth in gas will put substantial strain on the natural gas supply system
- Growth of CO<sub>2</sub> emissions in the power sector is below national average; SO<sub>2</sub> emissions are reduced substantially (78%)

- **Gas Limitations**

- If gas is limited, the alternative technology of choice is coal
- Substantial coal can be expected to come on-line
- Comes at economic and environmental cost

- **Gas Price**

- If gas prices remain at high levels, coal becomes competitive

- **Nuclear**

- For nuclear to compete, investment costs have to be substantially lower (48%)